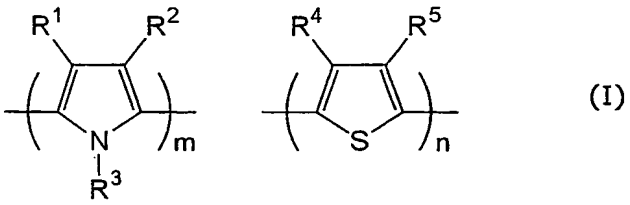
CLAIMS

1. A π-conjugated copolymer comprising a pyrrole-based unit and a thiophene-based unit represented by the general formula (I):

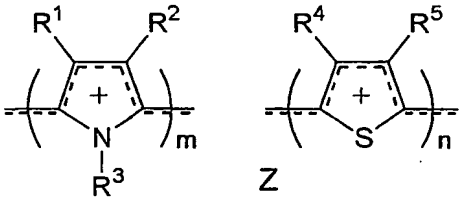


(I)

wherein R^1, R^2, R^4, and R^5 independently represent a monovalent group selected from the group consisting of hydrogen atom, linear or branched, saturated or unsaturated alkyl group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkoxy group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkyl ester group having 1 to 10 carbon atoms, halogen atom, nitro group, cyano group, primary, secondary or tertiary amino group, trihalomethyl group and phenyl group which may have a substituent, R^1 and R^2, and R^4 and R^5 may be bonded together at any positions respectively to form at least one 3 to 7-membered, saturated or unsaturated, hydrocarbon ring structure, the ring structure may arbitrarily contain a carbonyl bond, an ether bond, an ester bond, an amide bond, a sulfide bond, a sulfinyl bond, a sulfonyl bond, and an imino bond, the hydrocarbon forming the ring structure may have a group selected from the group consisting of linear or branched, saturated or unsaturated alkyl group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkoxy group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkyl ester group having 1 to 10 carbon atoms, halogen atom, nitro group, cyano

group, primary, secondary or tertiary amino group, trihalomethyl group and phenyl group which may have a substituent, R^3 represents a monovalent group selected from the group consisting of hydrogen atom, linear or branched, saturated or unsaturated alkyl group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkoxy group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkyl ester group having 1 to 10 carbon atoms, halogen atom, nitro group, cyano group, primary, secondary or tertiary amino group, trihalomethyl group and phenyl group which may have a substituent, and m and n represent a composition ratio of the π-conjugated copolymer and satisfy the conditions of $m+n=1$ and $0<m\leq 0.75$.

2. A π-conjugated copolymer comprising a pyrrole-based unit and a thiophene-based unit represented by the general formula (II), and an electrochemically and/or chemically doped structure:



(II)

wherein R^1, R^2, R^4, and R^5 independently represent a monovalent group selected from the group consisting of hydrogen atom, linear or branched, saturated or unsaturated alkyl group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkoxy group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkyl ester group having 1 to 10 carbon atoms, halogen atom, nitro group, cyano group, primary, secondary or tertiary amino group, trihalomethyl group and phenyl group which may have a substituent, R^1 and R^2, and R^4 and R^5 may be bonded together at any positions respectively to form at least one 3

to 7-membered, saturated or unsaturated, hydrocarbon ring structure, the ring structure may arbitrarily contain a carbonyl bond, an ether bond, an ester bond, an amide bond, a sulfide bond, a sulfinyl bond, a sulfonyl bond, and an imino bond, the hydrocarbon forming the ring structure may have a group selected from the group consisting of linear or branched, saturated or unsaturated alkyl group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkoxy group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkyl ester group having 1 to 10 carbon atoms, halogen atom, nitro group, cyano group, primary, secondary or tertiary amino group, trihalomethyl group and phenyl group which may have a substituent, R^3 represents a monovalent group selected from the group consisting of hydrogen atom, linear or branched, saturated or unsaturated alkyl group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkoxy group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkyl ester group having 1 to 10 carbon atoms, halogen atom, nitro group, cyano group, primary, secondary or tertiary amino group, trihalomethyl group and phenyl group which may have a substituent, m and n represent a composition ratio of the π-conjugated copolymer and satisfy the conditions of $m+n=1$ and $0<m\leq 0.75$, and Z represents a counter anion with dopability.

3. The π-conjugated copolymer according to claim 1, wherein the pyrrole-based unit is such that R^1 and R^2 in the general formula (I) independently represent a monovalent group selected from the group consisting of hydrogen atom, linear or branched, saturated or unsaturated alkyl group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkoxy group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated

alkyl ester group having 1 to 10 carbon atoms, halogen atoms and cyano group, alternatively R^1 and R^2 are bonded together at any positions to form a 3 to 7-membered, saturated or unsaturated, hydrocarbon ring structure that may contain an ether bond and/or a sulfonyl bond, and R^3 represents a hydrogen atom.

4. The π-conjugated copolymer according to claim 3, wherein the pyrrole-based unit is pyrrole.

5. The π-conjugated copolymer having the electrochemically and/or chemically doped structure according to claim 2, wherein the pyrrole-based unit is such that R^1 and R^2 in the general formula (II) independently represent a monovalent group selected from the group consisting of hydrogen atom, linear or branched, saturated or unsaturated alkyl group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkoxy group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkyl ester group having 1 to 10 carbon atoms, halogen atom and a cyano group, alternatively, R^1 and R^2 are bonded together at any positions to form a 3 to 7-membered, saturated or unsaturated, hydrocarbon ring structure that may contain an ether bond and/or a sulfonyl bond, and R^3 represents a hydrogen atom.

6. The π-conjugated copolymer according to claim 5 , wherein the pyrrole-based unit is pyrrole.

7. The π-conjugated copolymer according to claim 1 , wherein the thiophene-based unit is such that R^4 and R^5 in the general

formula (I) independently represent a monovalent group selected from the group consisting of hydrogen atom, linear or branched, saturated or unsaturated alkyl group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkoxy group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkyl ester group having 1 to 10 carbon atoms, halogen atom and cyano group, alternatively, R^4 and R^5 are bonded together at any positions to form a 3 to 7-membered, saturated or unsaturated, hydrocarbon ring structure that may contain an ether bond and/or a sulfonyl bond.

8. The π-conjugated copolymer according to claim 7 , wherein the thiophene-based unit is 3,4-ethylenedioxythiophene.

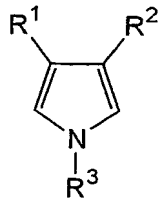
9. The π-conjugated copolymer having the electrochemically and/or chemically doped structure according to claim 2, wherein the thiophene-based unit is such that R^4 and R^5 in the general formula (II) independently represent a monovalent group selected from the group consisting of hydrogen atom, linear or branched, saturated or unsaturated alkyl group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkoxy group having 1 to 10 carbon atoms, linear or branched, saturated or unsaturated alkyl ester group having 1 to 10 carbon atoms, halogen atom and cyano group, alternatively R^4 and R^5 are bonded together at any positions to form a 3 to 7-membered, saturated or unsaturated, hydrocarbon ring structure that may contain an ether bond and/or a sulfonyl bond.

10. The π-conjugated copolymer according to claim 9 , wherein

the thiophene-based unit is 3,4-ethylenedioxythiophene.

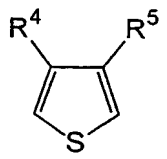
11. The π-conjugated copolymer according to any one of claims 2, 5, 6, 9 and 10, having an electric conductivity of 5 S/cm or more.

12. A method for producing a π-conjugated copolymer of claim 1 or 2, comprising copolymerizing a pyrrole-based compound represented by the general formula (III):



(III)

wherein R^1 to R^3 have the same meanings as defined in 1 above, and a thiophene-based compound represented by the general formula (IV):



(IV)

wherein R^4 and R^5 have the same meanings as defined in 1 above, by performing chemical oxidative polymerization in the presence of an oxidizing agent at a polymerization temperature of 60°C or lower.

13. The method for producing a π-conjugated copolymer according to claim 12, wherein the polymerization is carried out in the presence of a compound containing a counter anion with dopability.

14. The method for producing a π-conjugated copolymer according to claim 12 or 13 , wherein the pyrrole-based compound is pyrrole.

15. The method for producing a π-conjugated copolymer according to claim 12 or 13, wherein the thiophene-based compound is 3,4-ethylenedioxythiophene.

16. The method for producing a π-conjugated copolymer according to claim 12 or 13, wherein the oxidizing agent contains an iron salt or a persulfate salt.

17. The method for producing a π-conjugated copolymer according to claim 13, wherein the compound containing a counter anion with dopability is an organic sulfonic acid compound.

18. The method for producing a π-conjugated copolymer according to claim 12 or 13, wherein a mixed solvent of isopropanol and water is used in the polymerization.

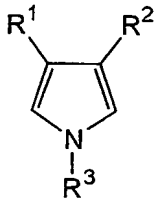
19. The method for producing a π-conjugated copolymer according to claim 12 or 13, wherein the polymerization temperature is 30°C or lower.

20. An article comprising an oxide film formed by electrolytically oxidizing a valve action metal, wherein the oxide film is coated with the π-conjugated copolymer described in any one of claims 1 to 11.

21. The article according to claim 20, wherein the valve action metal comprises at least one metal selected from the group consisting of aluminum, silicon, tantalum, niobium, titanium and zirconium.

22. A solid electrolytic capacitor, comprising as a solid electrolyte the π-conjugated copolymer described in any one of claims 1 to 11.

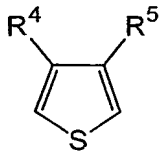
23. A method for producing a solid electrolytic capacitor in which a solid electrolyte layer comprising a π-conjugated copolymer is formed on a dielectric film of porous valve-action metal, which method comprises a step of polymerizing a pyrrole-based compound represented by the general formula (III):



(III)

wherein R^1 to R^3 have the same meanings as defined in 1 above, and a thiophene-based compound represented by the general formula

(IV)



(IV)

wherein, R^4 and R^5 have the same meanings as defined in 1 above,

by using a solution of an oxidizing agent having polymerization-initiating property singly or using a mixed solution of such an oxidizing agent and an electrolyte which contains a counter anion with dopability to form the π-conjugated copolymer on the dielectric film.

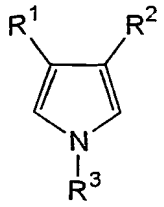
24. The method for producing a solid electrolytic capacitor according to claim 23, wherein the polymerization is carried out within a temperature range of -30°C to 40°C.

25. The method for producing a solid electrolytic capacitor according to claim 23, wherein the polymerization is carried out in the atmosphere of a relative humidity of 5% to 70%.

26. The method for producing a solid electrolytic capacitor according to claim 23, wherein the porous valve action metal contains at least one metal selected from the group consisting of aluminum, silicon, tantalum, niobium, titanium and zirconium.

27. The method for producing a solid electrolytic capacitor

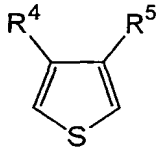
according to claim 23, comprising using pyrrole-based compound as represented by the general formula (III):



(III)

wherein R^1 to R^3 have the same meanings as defined in 3 above,

and using thiophene-based compound as represented by the general formula (IV):



(IV)

wherein R^4 and R^5 have the same meanings as defined in 7 above.

28. The method for producing a solid electrolytic capacitor according to claim 23, wherein the pyrrole-based compound is pyrrole and the thiophene-based compound is 3,4-ethylenedioxythiophene.

29. The method for producing a solid electrolytic capacitor according to claim 23, wherein the oxidizing agent having a polymerization-initiating property contains an iron salt or a persulfate salt.

30. The method for producing a solid electrolytic capacitor according to claim 23, wherein the electrolyte containing a counter anion with dopability contains an organic sulfonic acid compound.

31. The method for producing a solid electrolytic capacitor according to claim 23, wherein the polymerization step is carried out multiple times.

32. The method for producing a solid electrolytic capacitor according to claim 23, wherein the maximum thickness of the solid electrolyte layer formed on the dielectric film is 10 μm to 200 μm.